

# Yield and Fruit Quality of Tomato as Influenced by Calcium and Mulching in Rooftop Cultivation

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## Abstract

The experiment conducted in containers known as pot placed on rooftop of a building using noncalcareous grey terrace soil was carried out from October, 2012 to March, 2013 at Kazla, Motihar, Rajshahi, Bangladesh to investigate the influences of calcium and mulching practices on yield and fruit quality of tomato. The study was laid out in a split-split plot design with three replications. The trials comprised three factors: 1) three tomato varieties viz, BARI F<sub>1</sub>Tomato-5, BARI F<sub>1</sub>Tomato-6 and BARI F<sub>1</sub>Tomato-7; 2) four levels of calcium (Ca) treatment (40 ppm, 60 ppm, 80 ppm, 120 ppm) and 3) mulching practices. Results of the experiment revealed that fresh yield of tomato was significantly increased by applying mulching practices due to conservation of soil moisture by mulches and therefore, reduced Ca-deficiency symptoms. The highest number of fruits per plant and fresh yield were obtained from the variety BARI F<sub>1</sub>Tomato-5. The same trend of yield and yield contributing parameters were likely to be better by using T<sub>3</sub> treatment (80 ppm) than those of other treatments. In contrast, BARI F<sub>1</sub>Tomato-7 variety in control treatment without mulching practice gave poor quality and yield of tomato. Results suggested that BARI F<sub>1</sub>Tomato-5 variety receiving 80 ppm calcium treatment with mulching condition exposed better quality, yield and yield contributing characters of tomato. However, the T<sub>3</sub> treatment (80 ppm) with mulching would be recommended as the best combination to grow BARI F<sub>1</sub>Tomato-5 for the farmers in Bangladesh.

## Keywords

Tomato Varieties, Calcium Treatment, Rice Straw, Mulching Practices and Yield

## 1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is herbaceous plant and a member of

the solanaceae family. Tomato is one of the most important vegetable crops grown throughout the world under field and greenhouse conditions. Global production of tomato is over 120 million metric tons [1]. The average yield of tomato in Bangladesh is 7.42 t/ha, which is very low compared to other tropical countries. At present 6.10% area in Bangladesh is under tomato cultivation both in winter and summer [2]. In terms of human health, tomato is a major component in the daily diet in many countries, and constitutes an important source of minerals, vitamins, and antioxidants [3].

Container gardening is the practice of growing plants in containers instead of planting them in the ground. This gardening may also be known as pot cultivation. This type of cultivation reduces the risk of soil-borne diseases, virtually eliminates weed problems, and gives gardeners more control over moisture, temperature, and sunlight. The method of cultivating food on the rooftop is referred to as rooftop farming. Rooftop cultivation can also provide more opportunities for growing fresh produce for populations that have little ground area for crops, which can help reduce food shortages in poor, urban areas.

For high yield and good fruit quality, three plant nutrients such as Ca, Mg, and K must be in sufficient supply due to their functions in plant metabolism [4]. Blossom-end rot (BER) is a physiological disorder in tomato fruit that may reduce the marketable yield [5]. A high rate of BER occurrence has often been associated with low calcium (Ca) content in the fruit tissue [6]. Increasing fruit Ca uptake has been shown to effectively reduce the incidence of BER in tomatoes [7] [8] [9]. Yield of tomato is related with mulching. In winter or dry season mulching conserve soil moisture and modify the soil physical environment which causes nutrient availability for the plant and ultimately improve the yield of tomato. The experiment focuses to examine three varieties of tomato interacting with different calcium treatments and mulching to differentiate results on total number of fruits, defective fruits and weight of fruits per plant, and fresh yield per plant and per hectare. The objective of this study is to determine the best combination accomplishing suitable variety, treatment and mulching for better quality and yield of tomato and therefore recommend for Bangladesh.

## 2. Materials and Methods

The research work was designed for rooftop cultivation at Kazla, Motihar, Rajshahi city corporation Bangladesh during the period from October 2012 to March 2013 with an attempt to evaluate the effect of calcium and mulching on yield and yield contributing characters of tomato. Geographically the experimental field was located at 24°21'41.85"N latitude and 88°37'42.34"E longitude. The site was characterized by moderately high temperature and heavy rainfall during the kharif season and scanty rainfall with moderately low temperature during the Rabi season. The average temperature, humidity and rainfall were recorded as 22°C, 75% and 7 mm respectively during the experiment. The experimental soil was collected from Godagari terrace area, Rajshahi Bangladesh

which was categorized as noncalcareous gray terrace soil. It was silty clay loam in texture (sand 10%, silt 60%, clay 30%) with pH 6.0 and calcium content was 20.08 ppm. The soil was well drained with moderately high permeability. Soils were collected from a depth of 0 to 15 cm for making samples and then analyzed for determining physical and chemical characteristics before setting the experiment. The soils were analyzed at the Soil resource development institute (SRDI), Regional station, Shyampur and BCSIR Rajshahi.

Three tomato varieties viz, BARI F<sub>1</sub>Tomato-5, BARI F<sub>1</sub>Tomato-6 and BARI F<sub>1</sub>Tomato-7 were used as planting materials. Calcium carbonate (CaCO<sub>3</sub>) was used for supplying Ca, and the doses were 40 ppm, 60 ppm, 80 ppm, 120 ppm and control. Same doses were applied three times interval during the experimental tenure. At the beginning of the experiment calcium doses were mixed with pot soil before the day of transplanting. Secondly, the doses were applied at 20 day after transplanting (DAT) and finally applied at 40 DAT. Urea, diammonium phosphate (DAP) and muriate of potash (MP) fertilizers were applied as basal dose. Rice straw was used as mulching material. The treatments were replicated for three times.

The experiment was laid out in a split-split plot design. Each block was divided into two main plots, one plot was cultivated with mulching and another was without mulching. Each main plot was further divided into three sub-plots and varieties were allocated to these plots. Then each sub plot was again divided into five sub-sub plots and calcium (Ca) treatments were assigned to these plots at random. However, the total number of unit plots in the entire experimental plot was  $2 \times 3 \times 5 \times 3 = 90$ . Each plot was treated as individual earthen pot in the experiment. The data were analyzed statistically using the analysis of variance technique and the mean differences among the treatments were adjudged by Duncan's Multiple Range Test (DMRT) with the help of MSTAT software.

### 3. Results and Discussion

#### 3.1. Effect of Mulching

The effect of mulching method on the yield and yield contributing characters were presented in **Table 1**. Number of total fruits up to harvest, number of defective fruits, number of fresh fruits and fresh yield per plant and per hectare were significantly affected by mulching (M<sub>1</sub>). Maximum number of total fruits (28.22), fresh fruits (26.38) per plant and fresh yield (1.22 kg/plant or 60.25 t/ha) were recorded when mulch was applied causing conservation of soil moisture and weed control. Similar findings were recorded by Elkner *et al.* [10] in tomato. Alternatively, poor performance was observed in no mulching (M<sub>0</sub>) treatment. Fruit yield and yield contributing parameters of tomato also showed the similar trend (**Table 1**). No mulching created soil moisture stress which could lead to flower abortion, fruit drop and resultant low fruit count and low yield. This observation is consistent with the findings of Rowe-Dutton, Rudich *et al.*, and Pill and Lambeth [11] [12] [13] who reported decreased fruit count with increase in

soil dryness. Mulching had significant effect on single fruit weight, lateral length and pH of ripe fruit presented in the **Table 1**. The highest single fruit weight (46.51 g) was obtained in mulching ( $M_1$ ) meanwhile the lowest (41.60 g) was in no mulching ( $M_0$ ) technique. The similar result was reported by Kere *et al.* [14].

Defective fruits were correlated with mulching. Mulches can be used to protect plants against Ca-deficiency because they conserve soil moisture and therefore reduce Ca-deficiency symptoms (BER) and increase fresh fruits. In this study, defective number of fruit was decreased and number of fresh fruit was increased with mulching which ultimately increased fresh or marketable yield. Similar results were found by Streck *et al.*, John *et al.*, Elmer and Ferrandino, and Magnusson [15] [16] [17] [18].

### 3.2. Effect of Variety

Varietal performance showed significant effect on yield components. The number of fruits, defective fruits, fresh fruits per plant and fresh yield of tomato per plant and per hectare were presented in the **Table 1**. This table showed that BARI F<sub>1</sub>Tomato-5 variety ( $V_1$ ) gave the highest number of fresh fruits per plant and fresh yield than the other varieties. This might be occurred due to their genetic composition. The variation in yield may also be due to genetic differences among the varieties since they were grown under the same environmental condition.

The result was supported by Olaniyi and Fagbayide [19]. Varietal influence on yield of fruits per plant was reported by Sing and Sahu [20]. Rahman *et al.* [21]

**Table 1.** Effect of mulching on yield and yield contributing parameters of tomato.

Treatments	Total number of fruits/plant	Number of defective fruits/plant	Number of fresh fruits/plant	Average single fruit weight (g)	Total yield (kg)/plant	Weight of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
$M_1$	28.22	1.84	26.38	46.51	1.30	0.09	1.22	60.25
$M_0$	18.44	6.28	12.18	41.60	0.76	0.26	0.50	24.69
<b>LS</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>
$V_1$	29.47a	5.23a	24.23a	40.37c	1.20a	0.20a	1.00a	49.38a
$V_2$	22.00b	4.07b	17.93b	49.43a	1.10b	0.20a	0.91b	44.94b
$V_3$	18.53c	2.87c	15.67c	42.37b	0.80c	0.12b	0.68 c	33.58c
<b>LS</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>
$T_0$	21.33c	7.38a	13.94c	44.00	0.94c	0.33a	0.62c	30.62c
$T_1$	23.67b	3.94b	29.72b	44.67	1.06b	0.17b	0.89b	43.95b
$T_2$	22.89bc	2.72c	20.17b	44.50	1.02bc	0.12c	0.90b	44.44a
$T_3$	26.56a	3.39bc	23.17a	44.00	1.17a	0.14bc	1.04a	51.35b
$T_4$	22.22bc	2.83c	19.39b	43.11	0.96c	0.11c	0.85b	41.98c
<b>LS</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>NS</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>

In a column, figures bearing similar letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. LS = Level of significance, NS = Non-significant, \*\* = Significant at 1% level, \* = Significant at 5% level.  $M_1$  = Mulching,  $M_0$  = Without mulching,  $T_0$  = Control treatment,  $T_1$  = 40 ppm Ca,  $T_2$  = 60 ppm Ca,  $T_3$  = 80 ppm Ca,  $T_4$  = 120 ppm Ca,  $V_1$  = BARI F<sub>1</sub>Tomato-5,  $V_2$  = BARI F<sub>1</sub>Tomato-6,  $V_3$  = BARI F<sub>1</sub>Tomato-7.

also reported that different tomato cultivars behaved significantly different with each other regarding yield per plant.

The maximum defective fruits were observed in BARI F<sub>1</sub>Tomato-5 (V<sub>1</sub>) compare to other varieties (**Table 1**) in the same environmental condition. The defectiveness occurred due to blossom end rot (BER), fruit cracking etc. The varietal differences for defectiveness of tomato fruits occurred due to susceptibility to BER and fruit cracking. The obtained results are in partially supported by Adams and Ho [22]. In spite of it, BARI F<sub>1</sub>Tomato-5 (V<sub>1</sub>) produced the highest number of fresh fruits, resultantly gave the highest total fruit yield. The weight of individual fruit and dry fruit were significantly different as influenced by different varieties. The highest individual fruit weight was found from BARI F<sub>1</sub>Tomato-6 (V<sub>2</sub>) variety than the other varieties (**Table 1**). The variation among the varieties in respect of individual fruit weight and dry fruit weight were due to the varietal and genetic characteristics. Varietal influence on individual fruit weight was also reported by Meher *et al.* [23].

### 3.3. Effect of Calcium

Yield parameters were significantly influenced by calcium treatment, presented in **Table 1**. The highest fresh yield was obtained with T<sub>3</sub> treatment (80 ppm) due to highest number of fresh fruits and lower incidence of blossom end rot (BER) in comparison to other treatments. Similar results were reported by Hao and Papadopoulos [24]. Calcium treatment with 80 ppm concentration showed the highest fresh fruit yield (1.04 kg/plant or 51.35 t/ha) due to available concentration of calcium into the soil solution. Highly available concentration of calcium has been known to increase the tolerance of plants to stress, and it is conceivable that this may have led to the higher yields in our study. The results obtained from the study are in agreement with those obtained by Fletcher *et al.* [25]. Piva *et al.* [26] reported that increased calcium level in the nutrient solution, increase the calcium level in the fruit. Control treatment (T<sub>0</sub>) showed the highest defective

**Table 2.** Interaction effect of mulching and variety on yield and yield contributing parameters of tomato.

Interactions	Total number of fruits/plant	Number of defective fruits/plant	Number of fresh fruits/plant	Average single fruit weight (g)	Total yield (kg)/plant	Weight of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
M <sub>1</sub> V <sub>1</sub>	34.53	2.06d	32.47a	42.80	1.48	0.09c	1.38a	68.15a
M <sub>1</sub> V <sub>2</sub>	26.73	1.87d	24.87b	52.13	1.39	0.11c	1.30a	64.20a
M <sub>1</sub> V <sub>3</sub>	23.40	1.60d	21.80c	44.60	1.04	0.08c	0.97b	47.90c
M <sub>0</sub> V <sub>1</sub>	24.40	8.4a	16.00d	37.93	0.92	0.32a	0.60c	29.63b
M <sub>0</sub> V <sub>2</sub>	17.28	6.27b	11.00e	46.73	0.81	0.29a	0.52c	25.68c
M <sub>0</sub> V <sub>3</sub>	13.67	4.13c	9.53e	40.13	0.55	0.17b	0.38d	18.77d
<b>LS</b>	<b>NS</b>	<b>**</b>	<b>**</b>	<b>NS</b>	<b>NS</b>	<b>**</b>	<b>**</b>	<b>**</b>

In a column, figures bearing similar letter(s) or without letters are identical and those having dissimilar letters differed significantly as per DMRT. LS = Level of significance, NS = Non-significant, \*\* = Significant at 1% level, \* = Significant at 5% level. M<sub>1</sub> = Mulching, M<sub>0</sub> = Without mulching, V<sub>1</sub> = BARI F<sub>1</sub>Tomato-5, V<sub>2</sub> = BARI F<sub>1</sub>Tomato-6, V<sub>3</sub> = BARI F<sub>1</sub>Tomato-7.

fruits for insufficient calcium supply to the plant and produced the lowest fresh yield (0.62 kg/plant or 30.62 t/ha) (**Table 1**). Similar result was obtained by Bangerth [27].

### 3.4. Interaction Effect

#### 3.4.1. Mulching and Variety (M × V)

Interaction between mulching and variety had significant effect in respect of yield parameters presented in **Table 2**. The highest number of total fresh fruit and fresh yield per plant and per hectare were observed having the interaction effect of  $M_1 \times V_1$  due to mulching which conserve soil moisture and reduce moisture stress. Similar observation was found by Sharma *et al.*, [28].

The combination effect between mulching and variety exhibited significant variation in some yield components and yield of tomato observed by Kayum *et al.*, [29]. Number of defective fruits and weight of defective fruits per plant were lower in  $M_1 \times V_1$  interaction. In contrast, the highest number of defective fruits and defective fruit weight were observed in the interaction of  $M_0 \times V_1$  due to absence of mulching which caused moisture stress. However, BARI F<sub>1</sub>Tomato-5 ( $V_1$ ) variety was found to be as a mulching sensitive variety.

#### 3.4.2. Mulching and Calcium (M × T)

Calcium absorption problems can be prevented by mulching the soil around the tomato plants when it is damp, using straw, plastic or newspapers to keep the soil moisture level consistent. Tomato plants need available soil moisture during the period when they are most vulnerable to calcium deficiency, which is from the time they begin to set fruits until the time those fruits are at least one-half their mature size [30].

Significant effect was found in yield and yield contributing parameter of tomato with the interaction of mulching and calcium (**Table 3**). The highest number of fresh fruit and fresh yield were observed in the interaction of  $M_1 \times T_3$  due to moisture availability and optimum calcium concentration. Similar results were observed by Saeed and Ahmed in applying organic mulches with gypsum (for supplying Ca) to soil increased the growth and yield of tomato [31]. Uniform soil moisture must be maintained during the growth of tomato plant for easily up taking of calcium, soil should be kept moist, but not wet [32]. The highest number of defective fruits and defective fruit weight were found in the interaction of  $M_0 \times T_0$  due to no mulching and no calcium application. Similar observation was found by Jhon *et al.* [16].

#### 3.4.3. Variety and Calcium (V × T)

Yield contributing parameters of tomato were found significantly affected with the interaction of variety and calcium (**Table 4**). The maximum total number of fruits and fresh fruits per plant were greater with the interaction of  $V_1 \times T_3$ . The highest single fruit weight and fresh yield per plant and per hectare were observed in the interaction of  $V_2 \times T_3$ . However, calcium treatment at the dose of

**Table 3.** Interaction effect of mulching and calcium on yield and yield contributing parameters of tomato.

Interactions	Total number of fruits/plant	Number of defective fruits/plant	Number of fresh fruits/plant	Average single fruit weight (g)	Total yield (kg)/plant	Weight of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
M <sub>1</sub> T <sub>0</sub>	26.11	6.56b	19.56c	45.78	1.20	0.32ab	0.89c	43.95c
M <sub>1</sub> T <sub>1</sub>	28.44	2.22d	26.22b	47.33	1.33	0.11e	1.23b	60.74b
M <sub>1</sub> T <sub>2</sub>	27.78	0.44e	27.33b	47.11	1.29	0.02f	1.27b	62.72a
M <sub>1</sub> T <sub>3</sub>	31.67	0.00e	31.67a	46.56	1.46	0.00f	1.46a	72.10b
M <sub>1</sub> T <sub>4</sub>	27.11	0.00e	27.11b	45.78	1.23	0.00f	1.23b	60.74b
M <sub>0</sub> T <sub>0</sub>	16.56	8.22a	8.33f	42.22	0.69	0.35a	0.35f	17.28f
M <sub>0</sub> T <sub>1</sub>	18.89	5.67bc	13.22de	42.00	0.78	0.23cd	0.55de	27.16de
M <sub>0</sub> T <sub>2</sub>	18.00	5.00c	13.00de	41.89	0.74	0.21d	0.53de	26.17d
M <sub>0</sub> T <sub>3</sub>	21.44	6.78b	14.67d	41.44	0.88	0.28bc	0.61d	30.12b
M <sub>0</sub> T <sub>4</sub>	17.33	5.67bc	11.67e	40.44	0.69	0.23cd	0.47ef	23.21f
<b>LS</b>	<b>NS</b>	<b>**</b>	<b>**</b>	<b>NS</b>	<b>NS</b>	<b>**</b>	<b>**</b>	<b>**</b>

In a column, figures bearing similar letter(s) or without letters are identical and those having dissimilar letters differed significantly as per DMRT. LS = Level of significance, NS=Non-significant, \*\* = Significant at 1% level, \* = Significant at 5% level. M<sub>1</sub> = Mulching, M<sub>0</sub> = Without mulching, T<sub>0</sub> = Control treatment, T<sub>1</sub> = 40 ppm Ca, T<sub>2</sub> = 60 ppm Ca, T<sub>3</sub> = 80 ppm Ca, T<sub>4</sub> = 120 ppm Ca.

**Table 4.** Interaction effect of variety and calcium on yield and yield contributing parameters of tomato.

Interactions	Total number of fruits/plant	Number of defective fruits/plant	Number of fresh fruits/plant	Average single fruit weight (g)	Total yield (kg)/plant	Weight of defective fruits (kg)/plant	Fresh yield (kg)/plant	Fresh yield t/ha
V <sub>1</sub> T <sub>0</sub>	25.67	9.17	16.50de	41.33	1.07	0.38	0.69f	34.07f
V <sub>1</sub> T <sub>1</sub>	30.67	4.50	26.17ab	40.33	1.25	0.17	1.07ab	52.84ab
V <sub>1</sub> T <sub>2</sub>	29.50	3.17	26.33ab	40.67	1.22	0.12	1.09ab	53.83ac
V <sub>1</sub> T <sub>3</sub>	32.50	5.00	27.50a	40.00	1.30	0.18	1.12a	55.31a
V <sub>1</sub> T <sub>4</sub>	29.00	4.33	24.67bc	39.50	1.16	0.16	1.00bc	49.38bc
V <sub>2</sub> T <sub>0</sub>	20.50	7.33	13.17fg	49.83	1.03	0.38	0.67f	33.09f
V <sub>2</sub> T <sub>1</sub>	22.00	4.17	17.83de	49.00	1.09	0.21	0.89cd	43.95bc
V <sub>2</sub> T <sub>2</sub>	20.67	3.17	17.50de	49.00	1.02	0.15	0.87d	42.96d
V <sub>2</sub> T <sub>3</sub>	26.00	3.17	22.83c	50.67	1.33	0.15	1.18a	58.27a
V <sub>2</sub> T <sub>4</sub>	20.83	2.50	18.33d	48.67	1.03	0.12	0.91cd	44.94cd
V <sub>3</sub> T <sub>0</sub>	17.83	5.67	12.17g	40.83	0.73	0.25	0.50g	24.69g
V <sub>3</sub> T <sub>1</sub>	18.33	3.17	15.17ef	44.67	0.83	0.14	0.69f	34.07c
V <sub>3</sub> T <sub>2</sub>	18.50	1.83	16.67de	43.83	0.82	0.08	0.74ef	36.54ef
V <sub>3</sub> T <sub>3</sub>	21.17	2.00	19.17d	41.33	0.89	0.08	0.81de	40.00de
V <sub>3</sub> T <sub>4</sub>	16.83	1.67	15.17ef	41.17	0.71	0.07	0.64f	31.60f
<b>LS</b>	<b>NS</b>	<b>NS</b>	<b>**</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>**</b>	<b>**</b>

In a column, figures bearing similar letter(s) or without letters are identical and those having dissimilar letters differed significantly as per DMRT. LS = Level of significance, NS = Non-significant, \*\* = Significant at 1% level, \* = Significant at 5% level; V<sub>1</sub> = BARI F<sub>1</sub>Tomato-5, V<sub>2</sub> = BARI F<sub>1</sub>Tomato-6, V<sub>3</sub> = BARI F<sub>1</sub>Tomato-7, T<sub>0</sub> = Control treatment, T<sub>1</sub> = 40 ppm Ca, T<sub>2</sub> = 60 ppm Ca, T<sub>3</sub> = 80 ppm Ca, T<sub>4</sub> = 120 ppm Ca.

80 ppm ( $T_3$ ) along with the  $V_2$  variety gave the highest fresh yield than the other treatments due to decreasing of fruit defectiveness (**Table 4**). Bangerth [27] reported the same findings.

#### 4. Conclusion

With few exceptions, it can be concluded that the highest fruit yield with lower defective fruits were observed in BARI  $F_1$ Tomato-5 in receiving 80 ppm calcium treatment with mulching practices whereas, this variety showed the lowest performance in control treatment without mulching. However, the interaction treatment of 80 ppm calcium with mulching practices would be the best combination for growth and yield of BARI  $F_1$ Tomato-5 variety for the farmers in Bangladesh.

#### 5. Limitation of the Study

Indigenous varieties of tomato were not studied and compared to those of newer varieties used in this research. Different times of harvesting were not cited before the final harvest. The time of maturity would be different from each variety which may affect the yield and quality of tomato.

#### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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